CIHE

LEADERSHIP FOR BUSINESS AND HIGHER EDUCATION

Enhancing Value Task Force

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UK-INNOVATION RESEARCH CENTRE

Enhancing Impact

The value of Public Sector R&D

Summary Report

by Alan Hughes and Ben Martin, edited by David Docherty

Foreword

This is the second in a series of linked reports on gaining the most value from UK research, and in particular its publicly-funded research. The first report sets the UK's spend on R&D in an international context, and this follow-up assesses the impact of that expenditure. It highlights the many benefits of publicly-funded research, but stresses the vital importance of moving from simple measures of success, such as university spin-outs and patents, to a more nuanced understanding of the connections between public and private sectors in a system of knowledge production and innovation.

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"Universities are first and foremost designed to achieve a new understanding of natural phenomena and technologies: in this task they are naturally inventive. Conversely, in modern free market economies, it is firms that have the incentives and governance structures to make innovation their central goal, and are expected to be the almost exclusive sources of innovation."

Foray and Lisson, Handbook of the Economics of Innovation.

"It is the job of universities to ' top up the hopper' of ideas."

Ric Parker, Director of Research, Rolls Royce

The Enhancing Value Task Force was established to 'Identify and prioritise a small set of key actions for change that will enhance the value of publicly-funded research and collaboration with business.' In the first report[i], we provided an overview of the sources and nature of the £26.4bn invested in UK R&D, £8.4bn of which is government funded. We also identified three key aspects of the landscape:

- There is an R&D Funding Gap.

  Despite increased investment in higher education research, the UK is falling behind in R&D investment relative to its international competitors.

- R&D is concentrated in the UK's biggest firms.

  Our major corporations and their supply chains are vital components of the innovation system (only 3.5% of R&D is conducted by independent small and medium-sized firms, compared to the 34% contributed by our top ten firms).

- The UK innovation system is simultaneously open and vulnerable.

  Overseas investment in UK R&D is very high by international standards, which is a tribute to the openness of the system, but it means that the country is relatively vulnerable to strategic investment decisions made outside the UK.

In this, our second report[ii], we analyse the voluminous literature on the impact of publicly funded R&D on the UK economy, its firms, and society – including recent UK-IRC surveys - and identify a number of key conclusions.

- A wide range of qualitative and quantitative evidence shows that in the UK public sector research investment yields substantial benefits to society in economic and wider social terms.
- Where rates of return on public sector research funding can be sensibly estimated they are high (e.g. for health care in the range 10-25% over a 10-25 year time horizon).
- The pathways to impact of public sector research investment are however long, varied and complex, and final impacts on social and economic welfare depend critically on complementary investments being made by the private sector.
- The long time-scales and multiple inputs required to establish impact make quantification in general exceptionally difficult and this is exacerbated by the typically skewed distribution of positive impacts. As with all innovation-related investments, uncertainty produces outcomes in which a small number of successes account for the bulk of the impact.

- Where quantification is possible, it involves detailed analysis of multiple types of output and input. Attempts to reduce these to a single rate of return at the level of a project or the economy as a whole often requires heroic and questionable assumptions.
- It may thus be a serious policy mistake to rely on rate of return calculations as evidence of the health or otherwise of the innovation system. Moreover they give little policy guidance as to which pathways or processes and supporting investments actually led to the impacts.
- More sophisticated systems-based methods of impact measurement emphasising intermediate and trajectory-based measures must be adopted across the research and innovation landscape in order to guide policy development.

Pathways to impact

There are strong economic reasons for governments to invest public funds in innovation. Early stage far from market R&D is inherently uncertain, and companies may not be willing to take the risks necessary to achieve long-term benefit to the country. Furthermore, the value extracted by firms who do invest in innovation, may be less than the value to society as a whole because other firms may benefit from 'spillover' effects arising from their ability to piggy back on the knowledge generated by the orginal investing firm. Consequently governments – supported by business and civil society – must invest in R&D as part of their responsibility to drive economic growth. How success is measured, and how therefore to organise the system of public sector intervention to maximise success, is central to innovation strategies.

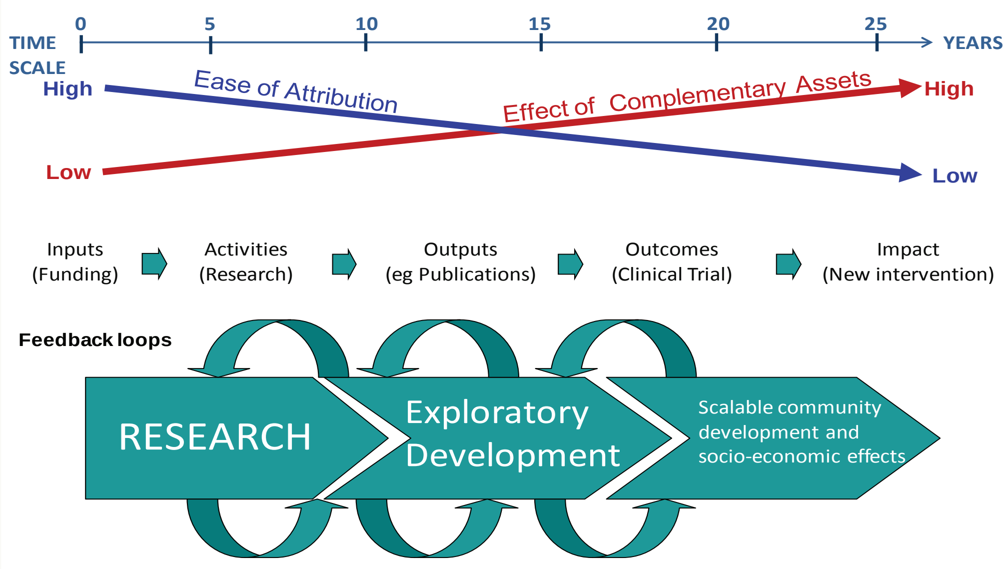
The Treasury impact assessment model, for example, proceeds in a linear fashion from activity to impact[1]. If you applied such Treasury logic to innovation, then activity (e.g. R&D) would lead to outputs (e.g. research papers and outcomes of clinical trials), and impacts (in terms of changes in overall productivity and performance resulting from, say, a new product or form of treatment).

By the most simple of output measures – namely articles, citations and usage per researcher – the UK is second only to the US as a research publishing nation. Moreover, it requires less research spend per publication than in comparator countries (Elsevier, 2011; p*assim*). And these papers are broadly used in industry: 44% of articles downloaded by corporate users were university-authored publications, with the rest made up equally of articles authored by hospitals, research institutes and firms. Likewise, more than 77% of all downloads of corporate-authored articles were by users in the academic sector. This suggests a rich pattern of interaction and a strong indication of the role of publications as a pathway to potential impact in the UK.

Publications are only one measure of impact, and tracking R&D into business, the economy and society remains a pressing issue in these fiscally difficult times. In reality, however, a much more complex model emerges than the Treasury model allows, with multiple feedback loops and pathways, and where the ability to measure the impact diminishes over time as the number of complementary players involved in successful implementation increases.

[1] For example, an impact review of a policy aimed at reducing the pool of long-term unemployed would need to assess a series of inputs - obtaining placements and undertaking training, improving qualifications etc. - in terms of their outputs, namely, increased jobs and lower unemployment.

Exhibit 1: Time, Attribution, Impact



Source: Hughes (2012)

Each publicly-invested pound moves along multiple pathways to achieve impact. As the US National Academy of Engineering notes: 'numerous diverse, robust, and often mutually reinforcing vectors link academic research to industry, including direct hiring of students, graduates, and faculty; temporary exchanges of researchers; faculty consultancy; industry-sponsored research contracts and grants; research centres; consortia; industrial liaison programmes; technology licensing; start-up companies; publications; and conferences'.[iii]

Numerous surveys of businesses and universities reinforce the idea that the impact of public sector funded research on the innovation system is dependent on the quality and nature of the interconnections between the university science base and the private, public and charitable sectors. These interconnections go far beyond transactions such as patenting and licensing, or creating new business spin outs. Relatively few academics take out patents or launch spin-out companies, but as Exhibit 2 shows many engage in consultancy and yet more in developing human capital.

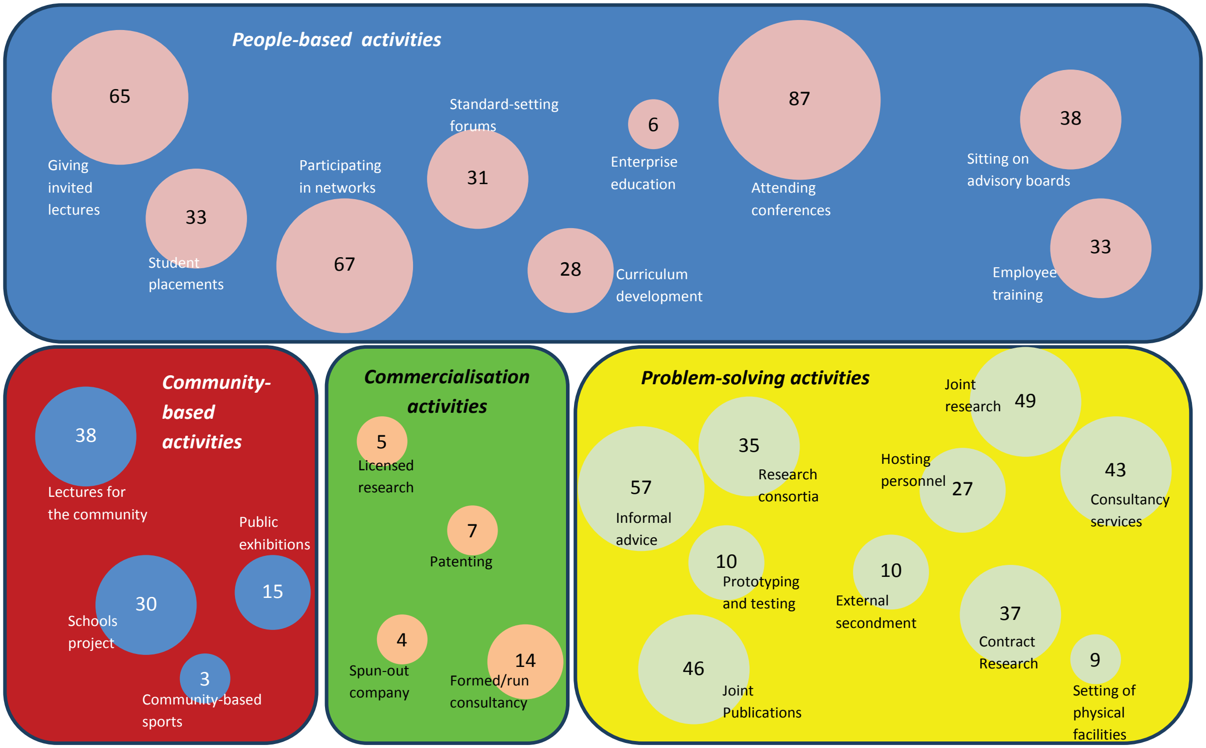
Exhibit 2: Commercialisation Activities by UK Academics 2005-2008 (%)

	Taken out a patent	Licensed research outputs to a company	Formed a spin-out company	Narrow Commercialisation	Formed or ran a consultancy via your research	Total Respondents
All	7.1	4.7	3.5	11.0	13.8	18,991
Health sciences	8.0	4.7	2.8	10.8	10.3	3,154
STEM	15.5	9.0	5.7	21.0	17.0	6,602
Arts and humanities	0.6	1.4	1.8	3.4	7.5	3,092
Social sciences	0.9	1.8	2.3	4.2	15.5	6,143
	**	**	**	**	**	

Source: Hughes and Kitson (2012)

*Note: ** Differences across subgroups statistically significant at 5% level or better*

Exhibit 3: Impact Pathways of UK Academics
(% of academics reporting each interation with an external organisation in the last three years)



Source: Hughes and Kitson (2012)

Note: Respondents were drawn from all disciplines in all UK higher education institutions and could record interactions in each of the pathways shown.

Exhibit 4: 'High interaction intensity' by discipline (%)[2]

	Narrow Commercialisation	Consultancy	Problem solving interaction	People based interaction	Community based interaction	All interactions	Total respondents
Health sciences	10.8	10.3	19.3	26.4	16.3	22.6	3,606
STEM	21.0	17.0	23.7	17.0	23.1	21.9	7,551
A&H	3.4	7.5	8.1	17.3	34.5	14.0	3,655
Social sciences	4.2	15.5	18.8	19.4	24.3	20.1	7,204
All (%)	11.0	13.8	17.7	21.7	22.2	20.2	
All (N)	19,090	19,034	3,842	4,763	4,705	4,452	22,016
	**	**	**	**	**	**	

Source: Hughes and Kitson (2012)

*Note: ** Differences across subgroup statistically significant at 5% level or better*

The surveys of academic intention and self-identified behaviour in Exhibits 3 and 4 are broadly consistent with data collected in the Higher Education Funding Council for England's Business Community Interaction Survey (HE-BCIS). The income from different external pathways to impact more than tripled in real terms between 2001 and 2010, showing that external users have become more willing to pay for access to university services, inputs and facilities. The largest component of pathway-related external income in 2010 was contract research, which generated £983million[3], followed by collaborative research at £749m, and Continuing Professional Development and Continuing Education at £580m. Regeneration and Development programmes, which are closely linked to regional and location-specific impact pathways, have been declining in recent years in real terms to £213m, and their share fell from 11% to 7%. Income from this pathway has been affected by the reorganisation of regional support policy in the UK and by the downward trend in EU and UK support for regional development.

Intellectual property (IP) was the least important source of income in all years tracked, except 2008-9, and accounted for only between 2% and 3% of income. It is important to gain some idea of the scale of these IP activities in terms of revenue flows or market values. The Russell Group of research-intensive UK universities have attempted to arrive at an estimate using

2 The final four columns of this table record the percentage of academics reporting that they used 50% or more of the individual interaction pathways relevant for each of the separate problem solving, people based and community domains. The final column records those using more than 50% of all pathways across the people based, problem solving and community domains combined.

3 This has increased in real terms in each year in the period covered and accounted for a share of total external pathway income which rose from 29% to 32% between 2003/4 and 2009/10.

data from 125 impact case-studies (Russell Group, 2010). They estimated that in the 66 cases where data were available, licensing revenues of just over £1bn had been generated over the previous 10 years. In the same period 24 companies had spun off with a combined estimated market value of £498m, and a further 24 had secured commercial investment of £330m. These impacts were highly skewed, with 80% of the combined returns across the case studies accounted for by just 20% of the cases. Indeed the top two cases (representing 3% of the sample) appear to have accounted for over £700m or around 37% of the overall total of £1.9bn (Russell Group, 2010, pp. 24-25 and Figure 3, p.25). Assessing the impact of the system of publicly-funded research on the basis of a limited number of successful transactional case studies is clearly too limited and we need a broader sense of how the inventive university system interacts with innovative businesses.

Absorbing Research

R&D activity in the private sector creates new knowledge in itself, but it also enhances the firm's 'absorptive capacity' – i.e. the ability of a firm to identify, understand and exploit knowledge developed elsewhere in the innovation system, including in the public sector. This goes to the heart of the crucial role of universities in increasing the stock of inventive ideas and practices in the innovation system and of the ability of firms and the economy to absorb them. The responsiveness of multi-factor productivity[4] to public sector research is higher when business R&D intensity in the economy is itself higher[iv].

In a survey of businesses conducted in 2004 and repeated in 2008, the majority say that the most important aspect of their decision to interact with a university was to gain 'access to state of the art research'.[v]

Exhibit 5: Factors influencing the decision to interact with universities, 2004 and 2008

	2004 % responding 'very important' or 'crucial'	2008 % responding 'very important' or 'crucial'
Access to state of the art research	66.1	57.3
Access to problem solving	52.1	42.6
Access to R&D facilities	52.1	41.4
Access to a research network	35.8	38.5
Seeking proprietary knowledge	22.5	32.8
To undertake exploratory research	30.0	30.6
Feedback for development process	24.0	26.6
To build up new research areas	29.7	25.7
Outsourcing R&D activities	21.5	15.2

Source: Bruneel et al. (2009)

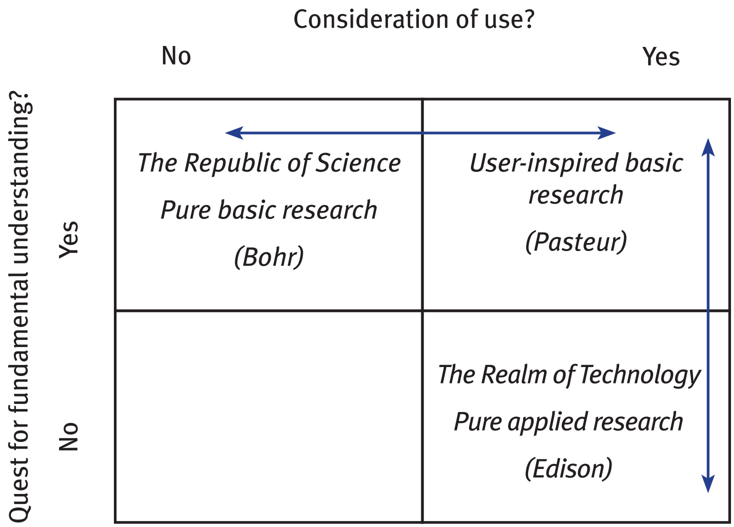
4 Labour productivity measures the output per unit of labour input, whereas multifactor productivity looks at a combination of labour, materials, and tangible assets (e.g plant and machinery) and intangible assets (e.g. training software R&D).

Similarly, in the CIHE's review of impact, the research directors of twelve of the UK's most intensive R&D companies noted: 'Although, naturally, we value the economic impact of research that our companies can build on, we are equally supportive of curiosity-driven work that has no obvious application at the beginning of its development, but which may have long-term value to business and society. Universities play a crucial role in searching beyond the horizon of what we currently know. And, because they are relatively free of the obvious business pressures that come from Return on Investment calculations, they can stimulate ideas that may be of great value in the long-run, but which also may be honourable dead-ends.'[vi]

In assessing impact and the flow of university inventiveness into business innovation, the old dichotomy between 'basic' and 'applied' research is therefore misleading and indeed increasingly irrelevant. It is better to think of different categories of research using Stokes' quadrants – i.e. those represented by Bohr ('pure' basic research), Edison ('pure' applied research) and Pasteur (use-inspired basic research or 'oriented basic research '). Much publicly funded research falls into Pasteur's Quadrant, and may stimulate movement between quadrants; and as Exhibit 5 and the comments above demonstrate, this is what innovative businesses are often searching for.

Exhibit 6: Stoke's Quadrants

Niels Bohr (1885-1962) won the 1922 Nobel Prize in Physics 'for his services in the investigation of the structure of atoms and of the radiation emanating from them.'



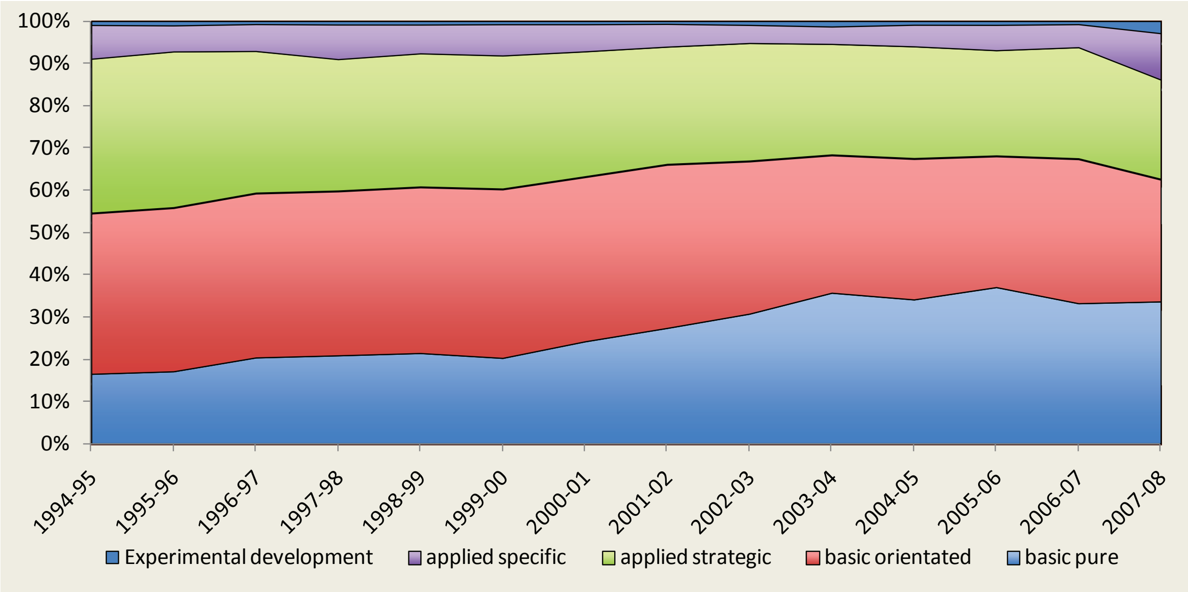
Louis Pasteur (1822-1895) One of the founders of medical microbiology, best known for his work on germ theory that led to major breakthroughs in vaccines, and for the Pasteurization process that bears his name. In 1895 he was awarded La Grand-Croix de la Légion d'honneur, the highest level of the award.

Source: Adapted from Stokes (1997) and Dasgupta and David (1994)

Thomas Alva Edison (1847-1931) was the pre-eminent inventor of his age, securing 1093 US patents over his life. His 1928 Congressional Medal of Honor citation declared: 'He illuminated the path of progress by his inventions.'

Both the measurements of the flow of funds in Exhibit 7, and a survey of how academics classify their own research in Exhibit 8 demonstrate the current substantial role of research in Pasteur's Quadrant as a driver of successful impact. The question, then, is how to understand and measure such systems of research and innovation, as well as the specific features of absorptive capacity.

Exhibit 7: The Distribution of UK Research Council Funding between Basic and Applied Research 1994 - 2008



Source: BIS SET Statistics: Science Engineering and Technology Indicators various editions.

Exhibit 8: Classification of Research Activity 2006-9 by UK Research Council Holders (% Respondents)

	Pure Basic research %	Oriented or User-inspired basic research %	Applied research %	Total respondents %
Arts and Humanities Research Council (AHRC)	35.0	33.6	31.4	789
Economic and Social Research Council (ESRC)	15.8	35.9	48.3	1,686
Science Research Councils such as BBSRC, EPSRC, MRC, NERC, STFC	19.9	35.1	44.9	3,168
Any Research Council	21.2	34.9	43.9	5,168
Share of Research Council Funding 2007-8*	33.7	28.9	34.6	

Source: CBR (2011a) and Exhibit 7

*Note: * calculated from Exhibit 7*

Note: The exhibit excludes the very small number that ticked ‘ None of the above apply to my research’ .

Questionable Measurement and Mixed Models

> *“Metrics-only approaches employing economic data and science, technology and innovation indicators were found to be behind the times: best practice combines narratives with relevant qualitative and quantitative indicators to gauge broader social, environmental, cultural and economic public value”*[vii]

Governments have a range of ways to influence the innovation system, and how they measure success has an impact on the system itself. Cincera et al. (2009) developed an empirical methodology for assessing the efficiency of the main policy instruments available to government to support R&D activities in the private sector. They distinguished between direct subsidies and tax incentives as supporting policies alongside R&D performed in the public sector. They reported that higher education expenditure on R&D has a positive impact on private sector R&D and on the number of R&D personnel employed in the business sector.

By themselves, econometric results such as these linking public sector R&D to output and productivity growth tell us very little about the process by which these impacts occur. They also depend on strong assumptions about the respective weights to be attributed to the inputs of capital, labour and knowledge stocks in deriving productivity estimates and the particular form of the functional relationship between inputs and outputs. In order to understand the systemic nature of impact, we must turn to richer data sets and more sophisticated models.

Systems models of impact analysis

Because of the long time-scales involved, in particular for research in Bohr's and Pasteur's quadrants, impact assessment models are increasingly assessing intermediate changes (such as the uptake of different pathways) and reviewing changes in collaborative behaviour. State-of-the-art assessments also now involve distinguishing between "forward tracking" and "backward tracking" narratives. The former takes a particular programme of research or a research project and attempts to trace its impact via subsequent developments "using" the research. The latter begins with an "impact", such as a major medical breakthrough to commercialisation and treatment, and then tries to trace backwards the key inputs to the events or breakthroughs contributing to the impact.

Examples of such analyses in health care find that the proportion of benefit attributable to UK research lies in the range from 10% to 25%, with a central estimate of 17% and with an estimated time lag of between 10 and 25 years. A large variety of impact assessments have been carried out covering the work of the research councils in the UK (de Campos, 2010).[5] Few produce a single estimate of the rate-of-return, although several identify various kinds of business benefits. For example, the Economic and Physical Sciences Research Council (EPSRC) carried out an economic impact evaluation of Innovative Manufacturing Research Centres (IMRCs) that identified the creation of 160 new jobs and the safeguarding of 230 more; £70m of additional sales; substantial increases in market share; 20 new technologies or products introduced to the market; licensing fees of £43m; and cost savings of £10m. In addition, eight spin-outs in the UK were created as well as 11 spin-outs overseas.

Our review spans numerous case studies relating to the social sciences, arts and humanities, as well as the engineering, medical and natural sciences, and each of them supports the argument we advanced earlier. A linear attribution of impact becomes less and less feasible the further the product, service or policy is from the initial research. However, intermediate or trajectory measures based, for example, on the strength of connectivity in particular pathways to impact, and investment in capacity building in both private and public sector R&D can be measured, and the overall output of the innovation system assessed by a combination of different methodologies. The purpose of such an approach, of course, is to improve the system and reduce barriers to productive behaviour. Evidence arising from the evaluation of policy interventions designed to enhance such intermediate innovation system components suggests significantly positive impacts.

Business Perspective on Barriers to Impact

University-Industry knowledge exchange in the UK is a 'full contact sport' spanning all business functions (not just innovation), and it reaches well beyond the science and engineering disciplines. The perceived constraints from a business perspective vary with industrial sector and the academic discipline companies interact with. The most frequently cited constraints are not motivational or cultural conflicts but the resources and time required by each party to develop and maintain knowledge exchange connections. A lack of mutual understanding and a strong orientation to basic research were seen as among the least important factors posing a barrier to interaction.

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5 It has been estimated that between 2000 and 2010 the UK research councils produced 96 documents dealing with impact of which 35 were impact studies and 19 internal evaluation reports (de Campos, 2010, Table 3).

Conflicts over time horizons are significant in some cases and IP may also be cited alongside a range of other transactional barriers. In a major study of firms collaborating on EPSRC grants, around two thirds of the companies cited constraints arising from the relatively long-term orientation of university research and the lack of suitable government programmes in specific research areas. Over 55% mentioned concerns regarding rules and regulations imposed by universities and governments in relation to confidentiality, intellectual property and the role of Technology Transfer Offices (TTOs).

A comparison of these firms between 2004 and 2008 suggested that there had been an increase in transaction costs experienced in working with universities. (It may be that because the survey in 2008 coincided with the period leading up to the Research Assessment Exercise (RAE) of that year, one consequence was a focus by academics on their publication record rather than their university-industry interactions as they approached the RAE submission date).

The greatest change related to the belief that some university TTOs had developed unrealistic expectations in relation to the value to be extracted from university-industry links. The number of businesses citing this barrier as very important or crucial doubled from 24% to 49% over the period from 2004 to 2008 (and both the barriers and the changes over time seem to be of equal significance for large and small firms in the sample). This may well be a consequence of government policies that encouraged universities to exploit their intellectual property more aggressively, leading to the development of clearer, stricter rules governing research and technology transfer relationships. These rules, in turn, may have led to more frequent and complex negotiations in launching collaborative research projects involving, in addition to the researcher and the company, the university's research administration and TTO. This emphasis on IP seems to have run counter to the intention of developing effective business-university collaborations.

Conclusion

We began with three challenges: overcoming the R&D funding gap in the UK, the need to support our major R&D investors and their supply chains, and the potential vulnerability of the UK innovation system to overseas decisions. In this short version of the main report, we have argued that in order to ensure continued investment by the UK government, major corporations and international businesses, we need to understand and measure the right things – namely, the linkages in the innovation system, and capacity building in people and facilities – and do it in the right way through narrative and data-rich methods. And we will turn to this in detail in our third report in the series on specific industrial sectors – energy, pharmaceuticals, construction, and the creative and digital industries.

Endnotes

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